Reconfigurable antennas radiations using plasma Faraday cage

Oumar Alassane Barro, Mohamed Himdi, Olivier Lafond

Reconfigurable Antennas Radiations Using Plasma Faraday Cage

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Abstract — **This letter presents a new reconfigurable plasma antenna associated with a Faraday cage. The Faraday cage is realized using a fluorescent lamp. A patch antenna with a broadside radiation pattern or a monopole antenna with an end-fire radiation pattern, operating at 2.45 GHz, is placed inside Faraday cage. The performance of the reconfigurable system is observed in terms of input reflection coefficient, gain and radiation pattern via simulation and measurement. It is shown that by switching ON the fluorescent lamp, the gain of the antenna decreases. This reconfigurable antenna can be used to avoid coupling with other communications or radar systems working in the same frequency band.**

1 INTRODUCTION

Plasma refers to the fourth state of matter. When the plasma inside a container (tube in our case) is energized (state ON), the media performs like a conductive element capable to reflect radio signals like a metal [1]. But, when the tube is de-energized (State OFF), the plasma is non-conductor and electromagnetic waves can go through it. In the literature, plasma can be used as radiator to replace metallic radiator or as reflector. The main advantage of plasma reflector or plasma antenna compared to metallic element resides in the possibility to use an electrical control rather than a mechanical one. In [2], the authors proposed plasma reflector antennas in order to steer the beam in certain directions. More recently, reconfigurable reflector plasma antennas have been realized by using low-cost commercial fluorescent lamps (CFL) [3]. On the other hand, a monopole fluorescent tube antenna was proposed in [4, 5].

In this letter, we present reconfigurable antennas using plasma faraday cage. A Faraday cage is an enclosure formed by a conductive material or by a mesh of such material. In our case, the Faraday cage is realized by using a fluorescent lamp which allows to switch ON or OFF the plasma and to obtain reconfigurable gain and radiation patterns.

The paper is organized as follows: in section II, the patch and monopole antennas as well as the Faraday cage modeling and simulations are presented. The comparison between simulation and measurement results is provided in section III. A conclusion is given in section IV.

2 MODELING AND SIMULATIONS

First, we design two different antennas. A circular patch operating at 2.45 GHz which radiates in broadside direction and a monopole operating also at 2.45 GHz with end-fire radiation. The geometry of the proposed patch antenna fed by coaxial line is shown in Figure 1(a). This circular patch with a diameter of 31 mm is printed on an FR4 substrate with thickness $h = 3.2$ mm, $\epsilon_r = 4.4$ and $\tan\delta = 0.025$.The diameter of the substrate is 50 mm. The antenna is fed by a 50 Ω coaxial line. The feed point is located along the y-axis, at a distance $d = 5$ mm from the center of the patch. The antenna is polarized along the y-axis and the ground plane is printed on the bottom side of the substrate.The designed quarter-wavelength monopole has a diameter of 2 mm and a height of 30 mm. This monopole is placed in the center of a ground plane with a diameter of 50 mm (Fig. 1(b)).

Secondly, a spiral shape lamp is modelized (Fig. 1(c)) [6]. The plasma diameter is 19 mm, the height of the lamp is 134 mm, its inner diameter is 60 mm, while the outer one is 98 mm and the gap between the coils is 3.64 mm. A ground plane of $200 \times 200\ mm^2$ is used in the bottom of the lamp in order to mask the electronic devices used to energize the plasma. The manufacturing prototypes and measurement setup are shown in Figure 2.

In simulation (the simulations are performed using CST Microwave studio [7]), the tubes containing the gas are made from lossy glass Pyrex with $\epsilon_r = 4.82$, $\tan\delta = 0.005$ and thickness of 0.5 mm. The plasma obeys to the Drude model defined by the equation (1).

$$\epsilon_r = 1 - \frac{\omega_p^2}{\omega(\omega - j\nu)} \tag{1}$$

where ϵ_r is the complex plasma permittivity, ω_p is the plasma angular frequency, ω is the operating angular frequency and ν is the electron-neutral collision frequency.

At the beginning, we used the same Drude model

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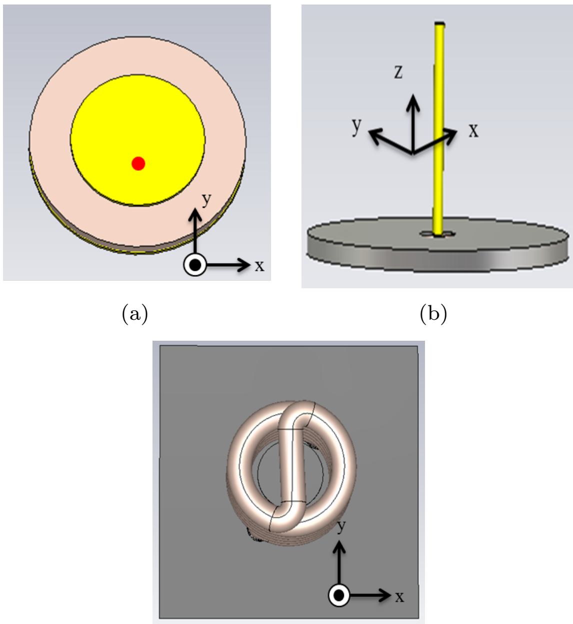

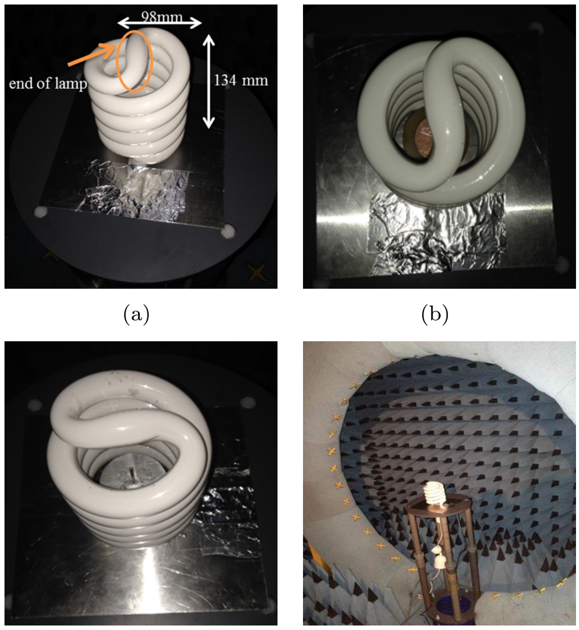

Figure 1: The designed models. (a) The patch antenna. (b) The monopole antenna. (c) The Fluorescent lamp.

Figure 2: Realized model. (a) Dimensions of plasma Faraday cage. (b) Patch antenna inside the plasma Faraday cage. (c) Monopole antenna inside the plasma Faraday cage. (d) Radiation pattern measurement setup (SATIMO)

as in [3], with the same parameters ($\nu = 900$ MHz and $\omega_p = 43.9823\ 10^9$ rad/s). Unfortunately, the simulation results were not in good agreement with measurements. Hence, we tried to match the simulations with the measurement by changing the plasma parameters defined in the Drude model. After retro-simulations, $\omega_p = 62.8318\ 10^9$ rad/s is considered and ν is kept equal to 900 MHz. In the absence of information from the manufacturer, the retro-simulation was necessary in order to have realistic plasma data for this kind of lamp.

3 RESULTS AND DISCUSSION

Simulated and measured S_{11} parameters are shown in Figure 3 for both patch and monopole cases and by switching ON or OFF the fluorescent lamp (Plasma ON / Plasma OFF). For the patch case and all configurations (patch alone, plasma OFF, plasma ON), the resonant frequency is close to 2.45 GHz and simulation and measurement are in good agreement (Fig. 3(a) and 3(b)). These results show that the matching of patch is not significantly affected by the plasma tube (ON or OFF). In the case of the monopole (Fig. 3(c) and 3(d)), the antenna is not well matched at the operating frequency in ON case. The plasma affects the antenna's resonance.

Radiation patterns have been measured in order to validate the simulation results. Measurements have been performed in a SATIMO anechoic chamber (near-fields setup) with peak gain accuracy equal to ±0.8 dBi. Figure 4 shows the measured and simulated radiation patterns at 2.45 GHz. For both simulation and measurements results, each radiation pattern is normalized to the maximum value of plasma OFF. It can be observed that the radiation patterns in measurement and simulation are quite similar. For the patch antenna, in both simulation and measurement the difference of gain between plasma OFF and ON at $\theta = 0$ (broadside) is 12 dB (Fig. 4(a), 4(b)). The gain of antenna is slightly decreased when the plasma is ON because the electric field polarization is parallel to the end of the lamp (Fig. 2(a)). For the monopole antenna (Fig.4(c) and 4(d)), the difference is lower, almost 5dB, because the electric filed polarization of monopole is orthogonal to the spiral part of the lamp. So the electromagnetic waves coming from the monopole are less attenuated.

Table 1 shows the maximum realized gain at 2.45 GHz for the patch and the monopole antenna cases. The simulation and measurement are in good agreement. It is interesting to note that the radiation of

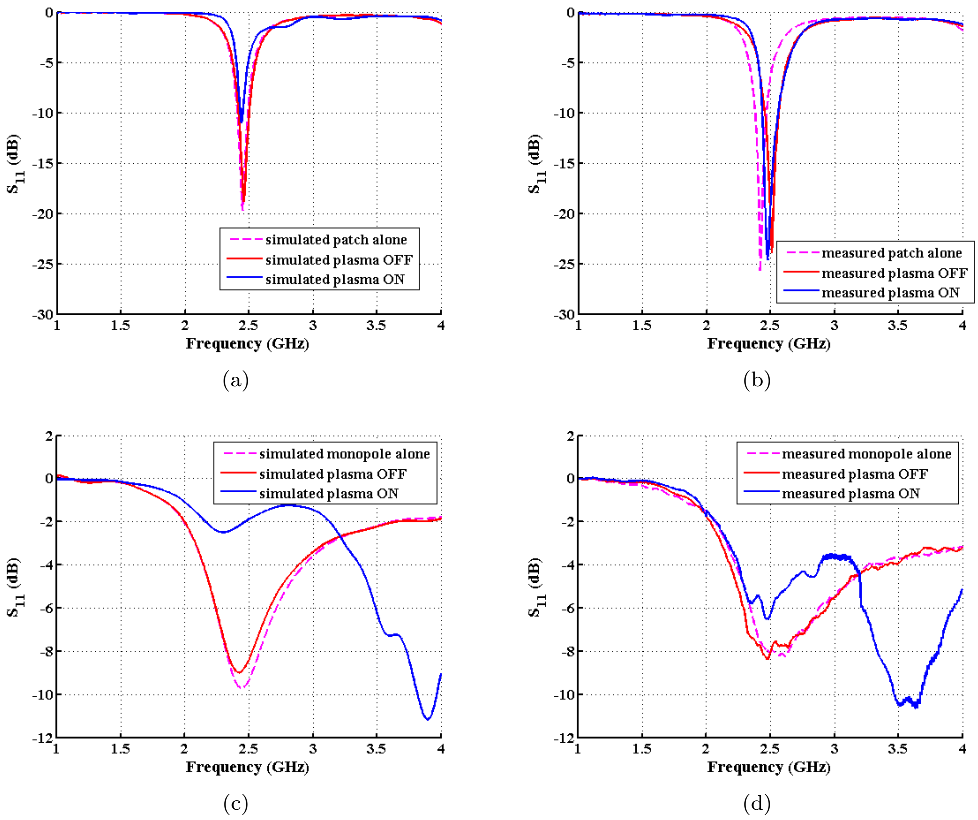

Figure 3: S_{11} magnitude parameter comparison. (a) Simulated S_{11} patch antenna case. (b) Measured S_{11} patch antenna. (c) Simulated S_{11} monopole antenna case. (d) Measured S_{11} monopole antenna.

Table 1: Maximum simulated and measured gain for the patch and monopole antennas

Configurations	**Patch antenna**		**Patch antenna**	
	Plasma OFF	Plasma ON	Plasma OFF	Plasma ON
Maximum simulated gain (dBi)	6.4	0.3	3.4	-1.3
Maximum measured gain (dBi)	5.5	-0.7	2.3	0.5

the patch can be strongly reduced when the plasma is ON. This means that the lamp acts as a Faraday Cage especially in the broadside direction. This behavior can be suitable if we want to avoid coupling this antenna and other near communication systems or to protect it against external undesirable signal.

4 CONCLUSION

In this letter, a Faraday cage using commercial Fluorescent Lamp (plasma) was presented. Two types of antennas were considered inside the lamp to show the impact of Faraday Cage on antenna radiation pattern and polarization. By switching OFF or ON the plasma, the lamp behaves like a transparent media or Faraday Cage respectively. This reconfigurability could be used to reduce antenna gain when different communication systems working at the same frequency are put close to each others. The results obtained in this paper show that the plasma Faraday cage with patch antenna is more interesting than the plasma Faraday cage with monopole antenna.

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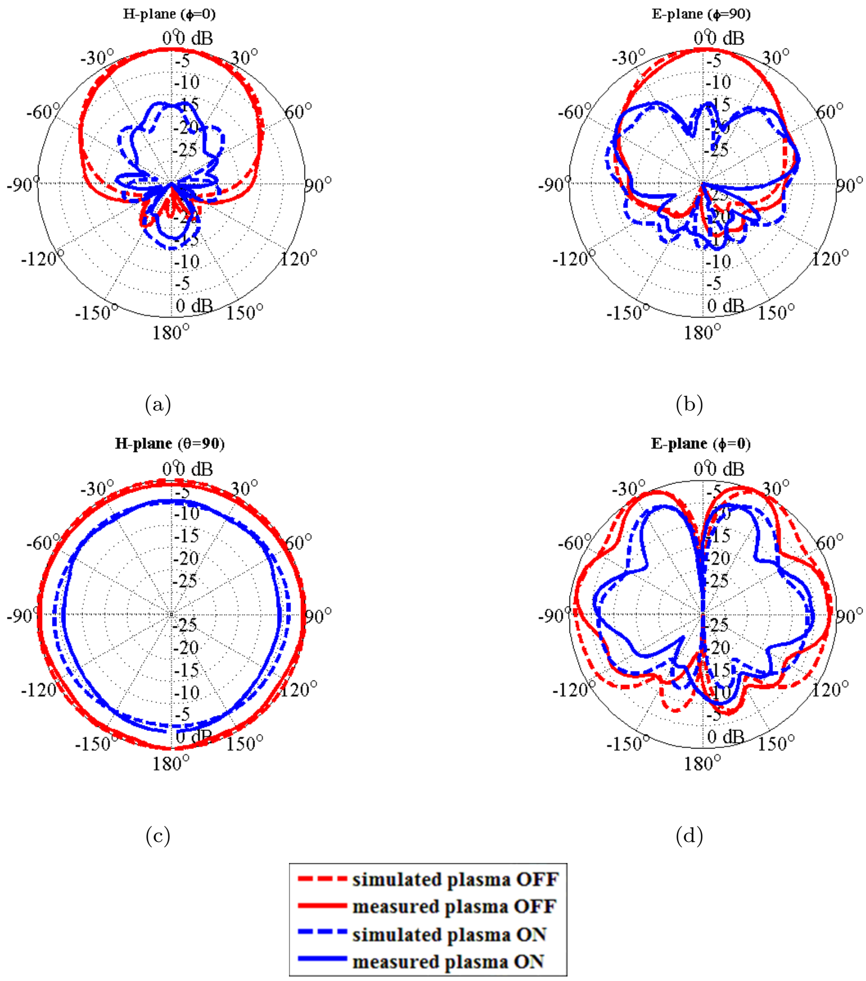

Figure 4: Normalized radiation patterns at 2.45 GHz. (a)-(b) Patch antenna case in the H-and E-planes respectively. (c)-(d) Monopole antenna case in H-and E-planes respectively.

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